

**Field Test Program for Long-Term
Operation of a COHPAC™
System for Removing Mercury
from Coal-Fired Flue Gas**

**Quarterly Technical Report
Reporting Period: October 1, 2003 – December 31, 2003**

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ABSTRACT

With the Nation's coal-burning utilities facing the possibility of tighter controls on mercury pollutants, the U.S. Department of Energy is funding projects that could offer power plant operators better ways to reduce these emissions at much lower costs. Sorbent injection technology represents one of the simplest and most mature approaches to controlling mercury emissions from coal-fired boilers. It involves injecting a solid material such as powdered activated carbon into the flue gas. The gas-phase mercury in the flue gas contacts the sorbent and attaches to its surface. The sorbent with the mercury attached is then collected by the existing particle control device along with the other solid material, primarily fly ash.

During 2001, ADA Environmental Solutions (ADA-ES) conducted a full-scale demonstration of sorbent-based mercury control technology at the Alabama Power E.C. Gaston Station (Wilsonville, AL). This unit burns a low-sulfur bituminous coal and uses a hot-side electrostatic precipitator (ESP) in combination with a Compact Hybrid Particulate Collector (COHPAC™) baghouse to collect fly ash. The majority of the fly ash is collected in the ESP with the residual being collected in the COHPAC™ baghouse. Activated carbon was injected between the ESP and COHPAC™ units to collect the mercury.

Short-term mercury removal levels in excess of 90% were achieved using the COHPAC™ unit. The test also showed that activated carbon was effective in removing both forms of mercury—elemental and oxidized. However, a great deal of additional testing is required to further characterize the capabilities and limitations of this technology relative to use with baghouse systems such as COHPAC™. It is important to determine performance over an extended period of time to fully assess all operational parameters.

The project described in this report focuses on fully demonstrating sorbent injection technology at a coal-fired power generating plant that is equipped with a COHPAC™ system. The overall objective is to evaluate the long-term effects of sorbent injection on mercury capture and COHPAC™ performance. The work is being done on one-half of the gas stream at Alabama Power Company's Plant Gaston Unit 3 (nominally 135 MW). Data from the testing will be used to determine:

1. If sorbent injection into a high air-to-cloth ratio baghouse is a viable, long-term approach for mercury control; and
2. Design criteria and costs for new baghouse/sorbent injection systems that will use a similar, polishing baghouse (TOXECON™) approach.

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EXECUTIVE SUMMARY

ADA-ES began work on a Cooperative Agreement with the Department of Energy in September 2002 to fully evaluate Activated Carbon Injection (ACI) in conjunction with a high-ratio baghouse (COHPAC™) for mercury control. The work is being conducted at Alabama Power Company's Plant Gaston. During the two-year project, a powdered ACI system will be installed and tested at the plant for a continuous one-year period. ADA-ES' responsibilities for managing the project include engineering, testing, economic analysis, and information transfer functions.

During the sixth reporting quarter, October through December 2003, progress on the project was made in the following areas:

- Held a team meeting at Gaston on October 20, 2003
- Performed low load test
- Measured fabric drag on select bags
- Removed select bags for strength analysis
- Installed new, high-perm bags
- Started baseline tests with new bags
- Collected baseline operating data with new bags
- Periodic measurements of hopper ash LOI

INTRODUCTION

Cooperative Agreement No. DE-FC26-02NT41591 was awarded to ADA-ES to demonstrate Activated Carbon Injection (ACI) technology on a coal-fired boiler equipped with a COHPAC™ baghouse. Under the contract, ADA-ES is working in partnership with DOE/NETL, Alabama Power, and EPRI.

A detailed topical report will be prepared at the end of the test. Quarterly reports will be used to provide project overviews and technology transfer information.

Team Members

This program is made possible by significant cost-share support from the following companies:

- Duke Power
- EPRI
- Southern Company and Alabama Power Company
- Hamon Research-Cottrell, Inc.
- Allegheny Power
- Ontario Power Generation
- TVA
- Duke Power
- Arch Coal, Inc.
- ADA-ES, Inc.

A group of highly qualified individuals and companies was assembled to implement this program. Project team members include:

- ADA-ES, Inc.
- Southern Research Institute
- Grubb Filtration Testing Services, Inc.
- Reaction Engineering International

EXPERIMENTAL

Activated Carbon Injection Equipment

The activated carbon injection equipment was installed, field-tested, and continues to operate.

Mercury Analyzer

The mercury analyzer is operating and measuring total vapor-phase mercury at the inlet and outlet of the COHPAC™ baghouse.

A full equipment description can be found in DOE Report No. 41591R03.

RESULTS AND DISCUSSION

Significant progress was made during this reporting period to meet the overall objective of demonstrating long-term performance of carbon injection for mercury control. The original test plan was adapted to the current operating conditions at the host site. These changes were documented in Report No. 41591R04, but primarily consisted of extending the baseline and optimization tests and modifying the injection scheme. The test plan for this program has five primary tasks:

1. Design and install an activated carbon injection system capable of continuous operation for up to one year.
2. Install a mercury analyzer capable of long-term, continuous operation. This analyzer is referred to as a Semi-Continuous Emissions Monitor (S-CEM).
3. Evaluate the long-term performance of carbon injection upstream of COHPAC™ for mercury control. This task has two separate test periods:
 - a. The first test (up to six months) will be conducted using the existing set of bags.
 - b. The second test (up to six months) will be conducted on a set of new bags made from advanced fabrics.
4. Perform short-term tests of alternative sorbents.
5. Document test procedures and results, and complete reporting and management requirements.

Tasks 1 and 2 have been completed. This report documents activities and presents results from task 3a, which was finished during this reporting period. Tasks 3b and 5 are in progress. Task 4 is scheduled to occur after Task 3 has ended.

Long-Term Performance Evaluation of Original (Existing) Bags

During this reporting period, testing with the original bag set was completed. The primary objective of this portion of the long-term evaluation task was to gather operation and performance data on the existing bags, while injecting activated carbon for mercury control. To do this, the original bag tests were divided into baseline, optimization, and long-term test periods. The baseline and optimization periods were then further subdivided because of unexpected baseline conditions that required repeating some of the initial test conditions. A summary of the test periods follows:

- Baseline Period 1 (March 28 – April 21)
- Baseline Period 2 (May 28 – June 26)
- Optimization Period 1 (April 21 – May 27)
- Optimization Period 2 (June 26 – July 18)
- Long-Term Test on Original Bags (July 19 – November 25)
- Long-Term Test on High-Perm Bags (December 15 – Present)

Team Meeting October 20, 2003

A team meeting was held at Plant Gaston on Wednesday, October 20. The purpose of the meeting was twofold: 1) to review project status and data and 2) to allow team members to tour the test site and see the equipment setup. Action items that came out of this meeting included:

1. Investigate whether the pressure drop set point to initiate a clean could be raised;
2. Investigate the possibility of running a low load test to simulate operation at a lower air-to-cloth ratio;
3. Perform additional tests on ash samples from the 2001 and 2003 baseline tests; and
4. Look into presenting mercury concentrations at the inlet and outlet as a cumulative value in pounds of mercury.

Each of these items was addressed and will be discussed in further detail in this report.

Long-Term Test Original Bags (July 19 – November 25)

Activated carbon was injected into the COHPAC™ baghouse nearly continuously from June 26 through November 25. During most of this time, the carbon injection control system was operating at an optimized condition to minimize impact on baghouse cleaning frequency while injecting sufficient carbon to maintain 80%. The control logic was programmed to vary carbon injection rate with respect to inlet mass loading. When baseline inlet loading and baghouse cleaning frequency are high, the impact on cleaning frequency is minimized by lowering or turning off carbon injection. Removal efficiency is not significantly impacted at these lower rates because the natural loading and mercury removal efficiency are higher. The control logic has the ability for three different carbon injection rates based on three ranges of inlet loading. The set points used during the long-term test with the original bags

are shown in Table 1. The maximum injection rate was set at either 16 or 20 lbs/h, depending on baghouse conditions and mercury removal.

Table 1. Activated Carbon Injection Operating Parameters.

Inlet Loading (gr/scf)	Inlet Loading (gr/acf)	Injection Concentration (lbs/MMacf)	Carbon Injection Rate (lbs/h)
<0.1	~0.07	0.52 or 0.66	16 or 20
<0.2	~0.14	0.35	10
>0.2	~0.14	0	0

Vapor-phase total mercury was measured at the inlet and outlet of the 3B COHPAC™. One S-CEM instrument was used to measure mercury from both locations, alternating between the two. During this reporting period, the analyzer was in operation 24 hours per day, 7 days per week. The analyzer was left running, unattended, over the weekends.

Inlet and outlet total vapor-phase mercury, calculated mercury removal, carbon injection concentration, baghouse cleaning frequency, and inlet mass loading are presented for this reporting period in Figures 1 and 2. All figures can be found at the end of this report. Average, weekly inlet and outlet mercury concentrations and mercury removal efficiency are presented in Table 4. The standard deviation of the average mercury removal efficiency can also be seen in this table. Figure 3 graphically shows daily and weekly averages of inlet and outlet mercury concentrations and mercury removal.

COHPAC™ Inspection by Hamon Research-Cottrell

On October 7, Michael Kelaher with Hamon Research-Cottrell was on-site to inspect the Unit 3 COHPAC™ baghouse. Michael was the project and start-up engineer for this system. His trip report can be found in Appendix A.

In summary:

- The baghouse was operating as well as could be expected with the existing operating conditions (inlet loading and load profile.)
- A test was conducted where decreasing the time between pulses from 20 seconds to 10 seconds doubled the cleaning frequency. This can be seen in Figure 1 as the spike in cleaning frequency on October 7.
 - This change increased the time between cleans on the A-side baghouse, but had no real effect on the B-side.

- If the goal is to increase the amount of carbon injected into the baghouse, there are three options
 - Pulse faster;
 - Reduce the particulate loading from the ESP; or
 - Increase the pressure drop setting.
- Any changes to the cleaning parameters were returned to previous settings while Ontario Hydro mercury measurements were made on October 8 and 9.

Based on the results of Michael's visit, on October 10 plant personnel decreased the time between cleans from 25 to 19 seconds (a 25% decrease). At this setting, the maximum cleaning frequency increased to 5.5 from 4.1 pulses/bag/hour. This change can also be seen in Figure 1. On October 28, the time between pulses was returned to 25 seconds. The major difference in the cleaning with the higher, maximum pulse frequency was that during low load conditions the baghouse was able to recover faster and come out of continuous clean.

Increasing the pressure drop setting to initiate a clean was not an option.

Ontario Hydro Mercury Measurement Tests

A set of Ontario Hydro tests was conducted across the Unit 3B COHPAC™ baghouse on October 8 and 9. This method measures total mercury, including particulate, unlike the S-CEMs that only measure vapor-phase mercury. In addition, multiple metals sampling, following Method 29, was conducted on the outlet, and hydrogen chloride (HCl) sampling was conducted on the inlet.

The results from these tests have not yet been received.

Low Load Tests

Throughout these tests, the higher than expected mass loading into COHPAC™ has limited the quantity of carbon that can be injected. Although the test plan was altered to accommodate these real-life conditions, the question of how this information can be used in the design of new TOXECON™ systems is left virtually unanswered.

One thing that is clear from these tests is that the current air-to-cloth ratio is too high for a new TOXECON™ design. An educated estimate is that the ideal air-to-cloth ratio will be about 6.0 ft/min. In the team meeting, it was suggested that one way to overcome the operating limitations was to operate at low load/lower flow for an extended period. While at these conditions, increase the injection concentration to track both mercury removal and baghouse cleaning frequency.

Mark Berry, Southern Company, was able to schedule an extended period of low load operation for Unit 3. This is a complicated request, and probably will not be available again, because operating at low load is often in conflict with the company directives.

Full load at Gaston is nominally 270 MW. At this load, the flow rate into the 3B baghouse is nominally 520,000 acfm. Starting on November 5, Unit 3 operated at 195 MW for a 72-hour

block of time. The nominal flow at this condition is 375,000 acfm. Table 2 summarizes the differences in key variables at these two load conditions.

Table 2. Flow and air-to-cloth (A/C) ratio during low load test.

Unit 3 Boiler Load (MW)	270	195
~Unit 3B Flow (acfm)	520,000	375,000
~Unit 3B A/C ratio (ft/min)	~8.0	~6.0

The primary objective for this test was to gather performance data at a lower air-to-cloth ratio. The specific test goals were to 1) target higher carbon injection rates that will achieve 90% removal and 2) determine the impact of carbon injection on cleaning frequency at this lower air-to-cloth (A/C) ratio.

The test plan was developed to target three different injection rates in increasing order and is presented below:

1. Start with the current injection rate of 20 lbs/h (0.66 lbs/MMacf). At 195 MW, this will be equivalent to 0.9 lbs/MMacf. The thought behind this is to have comparable removal and cleaning frequency data to our current conditions.
2. Thursday, November 6 - increase injection to 45 lbs/h (2.0 lbs/MMacf). Based on our parametric tests from 2001, this rate should easily achieve 90% removal.
3. Friday, November 7 - after looking at data, decide whether to increase injection concentration to 2.5 lbs/MMacf, 3 lbs/MMacf, or to leave it the same. Return to normal operation Friday evening.
4. Mercury measurements - standard operation of measuring total vapor-phase mercury at the inlet and outlet.
5. Ash sample - collect samples daily.

Figure 4 shows a summary of the mercury measurements and cleaning frequency during this test period. In general, the test plan was carried out. Unfortunately, two problems came up. First, the baghouse computer stopped logging data Wednesday morning. This was fixed on Thursday morning. Second, when we turned the injection rate up to 2 lbs/MMacf, no improvement in removal was seen. Based on experience, the results were suspicious. Site personnel starting checking everything that might cause suspect data: the analyzers, the distribution manifolds, the hoses, etc. One thing they found was that the screw in the carbon feeder did not appear to be turning, even though the motor shaft was turning. Fortunately, this system has two feeder trains, so operation was switched to the other side. Within the next couple of hours, the outlet mercury concentration began to decrease and the removal efficiency increased.

Table 3 presents a summary of the results from this test. At 0.9 lbs/MMacf, the removal efficiency was about 84%, which is what was seen before the load was lowered. The cleaning frequency was estimated to be 0.6 pulses/bag/hour.

Table 3. Results summary from low load tests, November 5 – 7, 2003.

Injection Rate (lb/h)	Injection Concentration (lbs/MMacf)	Inlet Hg Concentration (µg/Nm ³)	Outlet Hg Concentration (µg/Nm ³)	RE (%)	Cleaning Frequency (pulses/bag/hour)
20	0.9	20.6	3.2	84.2	0.6 ^c
45 ^a	2.0	21.9	3.9	82.3	0.8
45 ^b	2.0	22.2	1.0	94.6	0.8
70	3.3	21.4	0.61	97.1	1.4

a. First 5 hours of 45 lb/h test. Switched feeders towards the end of this test.

b. Last 18 hours of 45 lb/h test.

c. Cleaning frequency estimated from data collected at the end of this test. Actual cleaning frequencies were not available because the COHPAC™ computer was not working.

For the first five hours after the injection concentration was increased to 2.0 lbs/MMacf, the removal efficiency stayed about the same at 82.3%. After the injection equipment and mercury analyzer were checked, the removal efficiency increased to 94.6%. Unfortunately, we cannot definitively say which change made the difference in the mercury removal. Switching feeders was probably the reason, but as Figure 4 shows, the decrease in outlet mercury did not start immediately after the feeders were switched. Once the feeders were switched, very high mercury removal was maintained for eighteen hours. The cleaning frequency during this time was 0.8 pulses/bag/hour, which is acceptable and leaves room for performance degradation over time.

The injection concentration was then raised to 3.3 lbs/MMacf for about 8 hours. Mercury removal increased to 97.1% and the cleaning frequency increased to 1.4 pulses/bag/hour. The cleaning frequency at this condition is probably at the limit of acceptability for a short-term test.

For a short period (50 minutes) at the end of the 3.3 lbs/MMacf test, the injection concentration was increased to 5.5 lbs/MMacf. No additional increase in mercury removal was seen and the test was not long enough to see a change in cleaning frequency.

Inlet grain loading from the BHA instruments was less than 0.018 gr/acf throughout the test.

Analysis and Interpretation of Figures 1 – 3 and Table 4:

Mercury control and measurements:

- Figure 3 and Table 4 present average mercury concentrations and efficiencies. The average inlet mercury concentration for the entire long-term test was 14.3 $\mu\text{g}/\text{Nm}^3$, with daily average concentrations varying between nominally 5.1 to 25.6 $\mu\text{g}/\text{Nm}^3$.
- The average outlet mercury concentration for the same period was 2.1 $\mu\text{g}/\text{Nm}^3$, with daily average concentrations varying between 0.24 and 6.2 $\mu\text{g}/\text{Nm}^3$.
- Average mercury removal during this four-month period was 85.6%, with a minimum daily average of 63.5% and a maximum daily average of 98.1%. The maximum carbon injection concentration was 0.66 lbs/MMacf, and at times carbon injection was turned off. The average injection concentration over this period was 0.55 lbs/MMacf. The Phase I tests predicted a removal efficiency of about 50% at this injection rate (Figure 5). These longer-term tests showed that high removal (>80%) could be achieved using less carbon than predicted.
- For the long-term test, an estimate of cumulative pounds of mercury entering and exiting the Unit 3B baghouse was calculated using the average inlet and outlet concentrations and flue gas flow measured continuously in the inlet duct with Kurtz flow instruments. The estimates are:
 - Inlet = 48 lbs
 - Outlet = 41 lbs.
- About 12,000 pounds of carbon were injected during this long-term test. The phase I tests predicted that over double this amount would be necessary to achieve about 80% mercury removal.
- Periods of rapidly changing mercury concentrations presented the most difficult conditions in which to maintain high mercury removal. This can be seen in three different examples by the decrease in mercury removal efficiency:
 1. October 14 – 16 in Figure 1
 2. October 29 – 30 in Figure 1
 3. November 10 in Figure 2

It is possible that the data from October 29 – 30 may be questionable because the solenoid valves in the analyzer were sticking. These data were left in, however, because it could not be confirmed that the analyzer problems affected the measurements. These data should be considered suspect.

Ash and Coal Samples

Coal samples were collected daily and ash samples were collected periodically from both the A- and B-side COHPAC™ hoppers, and from the hot-side ESP hopper. LOI of ash samples are measured periodically.

Table 4. Average weekly inlet and outlet mercury concentrations, and mercury removal efficiency.

Week Starting	Inlet Mercury ($\mu\text{g}/\text{m}^3$)	Outlet Mercury ($\mu\text{g}/\text{m}^3$)	Mercury Removal (%)	Standard Deviation Hg Removal
7/20/03	9.2	0.8	91	6.5
7/27/03	11.8	0.8	93	3.6
8/3/03	18.1	1.6	91	4.5
8/10/03	13.0	1.6	87	10.7
8/17/03	14.9	2.0	86	12.0
8/24/03	13.9	2.9	79	6.3
8/31/03	13.2	1.7	87	5.7
9/7/03	13.1	2.3	82	6.3
9/14/03	16.7	3.8	77	10.6
9/21/03	11.8	1.9	83	7.3
9/28/03	11.3	1.1	90	1.6
10/5/03	15.8	2.16	86	6.3
10/12/03	15.8	3.1	80	8.7
10/19/03	11.6	1.6	86	6.2
10/26/03	15.2	3.5	77	14.6
11/2/03	19.2	2.4	87	6.6
11/9/03	17.6	3.2	82	6.5
11/16/03	14.9	1.9	87	7.1
Overall Average	14.3	2.1	85.6%	

Baseline Test Ash and Coal Analyses

To better understand the differences between the 2001 and 2003 carbon injection, additional analyses of ash from 2001 and 2003 were undertaken. These analyses included:

- Particle size distribution by Malvern analysis (light scattering)
- N₂ BET surface area
- Petrography (analysis of coal macerals)
- Ultimate analysis
- Microscopy

Petrographic and ultimate analyses were carried out by Jim Hower at the University of Kentucky, Center for Applied Energy Research. Microscopy, particle size distribution, and N₂ BET surface area tests were carried out by Microbeam Technologies, Inc.

A report summarizing the results of these tests is presented in Appendix B. The conclusions were:

- Particle size distribution, surface area, carbon content, and carbon maceral type were all distinct between the hot-side ESP samples and the baghouse ash samples. The A-side ash had a lower surface area than the hot-side ESP ash, which may be due to differences in the distribution of carbon macerals in the ash. Addition of activated carbon to the baghouse increased the surface area, as one would expect.
- The A-side ash had LOI values comparable to the hot-side ESP ash. However, the carbon content of the A-side ash was lower than the carbon content of the hot-side ESP ash. The measured amounts of LOI agree well with the measured amounts of carbon for the hot-side ESP ash and the B-side ash sample (containing activated carbon). The measured amount of carbon in the A-side ash was considerably lower than the LOI. Based on the ultimate analysis of the ash, the A-side ash had a significant amount of moisture, sulfur, and oxygen, unlike the hot-side ash samples and the B-side sample. Based on two sets of samples, therefore, it appears that the LOI content of the A-side ash is misleading in terms of the amount of carbon in the ash.
- The hot-side ESP ash in 2003 did not differ greatly from the hot-side ESP ash from 2001 in terms of the carbon maceral content or particle size distribution. The surface area of the 2003 hot-side ESP ash was higher than in 2001. Thus, it is hard to determine if the boiler produced the same kind of ash in 2003 as in 2001. Since the number of samples measured was small (and different coals are burned in the boiler on a continually changing basis), it may be difficult to conclude with certainty that the combustion conditions are the same.
- The A-side samples for 2003 were significantly different from the 2001 samples in that the former contained more large particles. The variability in the 2003 A-side ESP ash suggests that the hot-side ESP was not operating in a consistently efficient manner, and that more large particles were getting through the hot-side ESP in 2003 as compared to 2001.

High-Perm Bag Baseline Test (December 15 – January 6)

The new high-permeability (high-perm) bags were installed December 4 – 8. The primary differences in design are denier (an indication of fiber diameter; 2.5 versus 7.0 denier) and permeability (nominally 30 versus 130 cfm/ft² @ 0.5" H₂O). The bag change-out was performed with the unit on-line. Crews worked round the clock to remove the old bags and cages, and install the new bags with the same cages. Prior to start-up, the bags were precoated with a silicon material called Nutralite, which was supplied by BHA Group. For the first week after the bags were installed, the baghouse was operated at partial flow by opening the bypass dampers on the B-side. This precaution is taken as part of standard start-up procedures. On December 15, the Unit 3B baghouse began filtering full flow.

The tentative schedule for the high-perm bag test is:

- Baseline Tests: December 15 – January 5
- Optimization Tests: January 6 – 23
- Long-Term Test: January 24 – TBD

Figure 6 presents inlet and outlet mercury concentrations, mass loading, and pulse frequency for the Unit 3B baghouse from December 15 through the end of the month. The S-CEM was not in service over Christmas week. Stack opacity is also shown in Figure 6. This stack is used to exhaust flue gas from both Units 3 and 4. Unit 4 was offline from the beginning of December until December 20, which provided a limited opportunity to track the opacity from Unit 3.

Interestingly, the stack opacity appears to follow the trends of both the inlet mass loading and the cleaning frequency. Comparing the opacity and cleaning frequency, a pattern can be seen on December 16 – 18 that when the baghouse cleans, there is a small spike in opacity. At times (December 20), it also appears that stack opacity follows inlet mass loading. Because of the design of these high-perm (7-denier) bags, they are not as efficient as the standard (2.7-denier) bags. It is believed that over time the difference in emissions from these two bag designs would decrease. It should be noted in Figure 6 that there appears to be an offset in the opacity numbers. It looks like an opacity of 2 should really be the zero level.

Cleaning frequency is significantly lower with the new bags, even with similar inlet mass loading conditions. Baseline cleaning frequency is consistently less than 1 pulses/bag/hour, except for a period with high loading where the frequency increased to nearly 2 pulses/bag/hour.

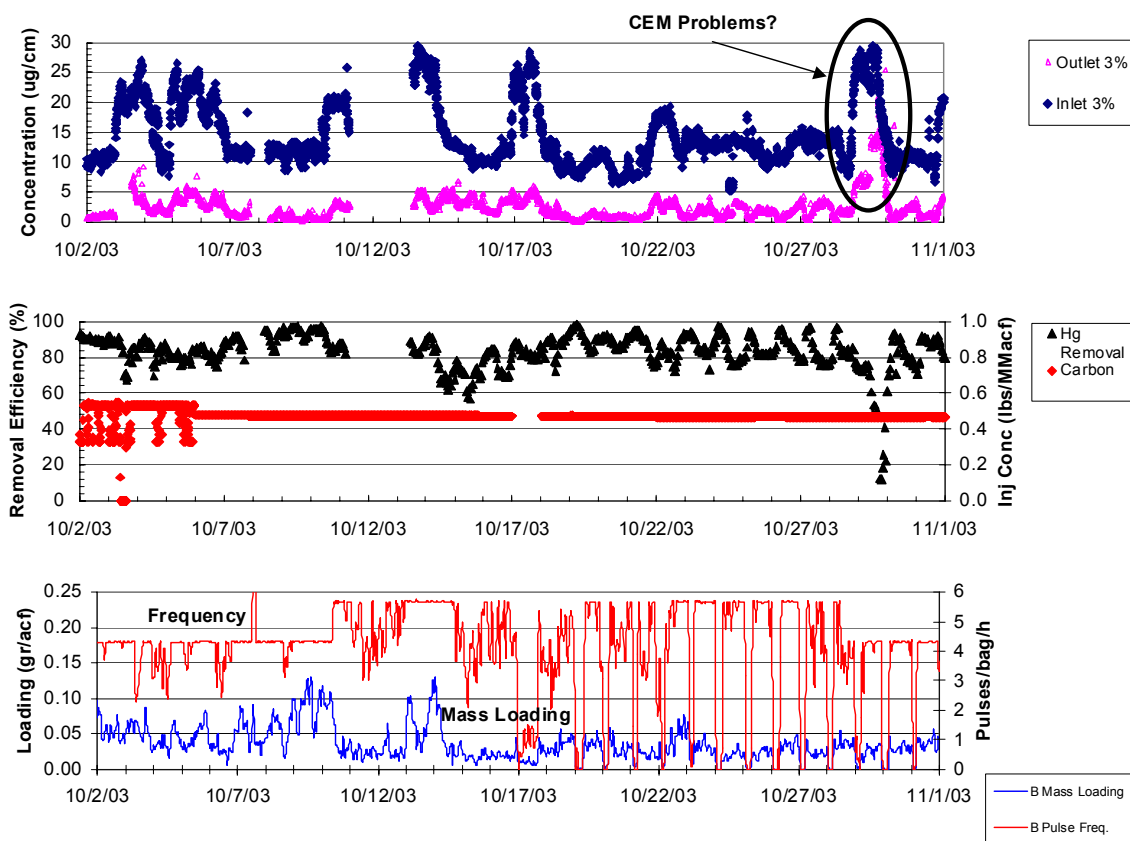


Figure 1. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC™ cleaning frequency and inlet mass loading on Unit 3B COHPAC™ from October 2 through November 1.

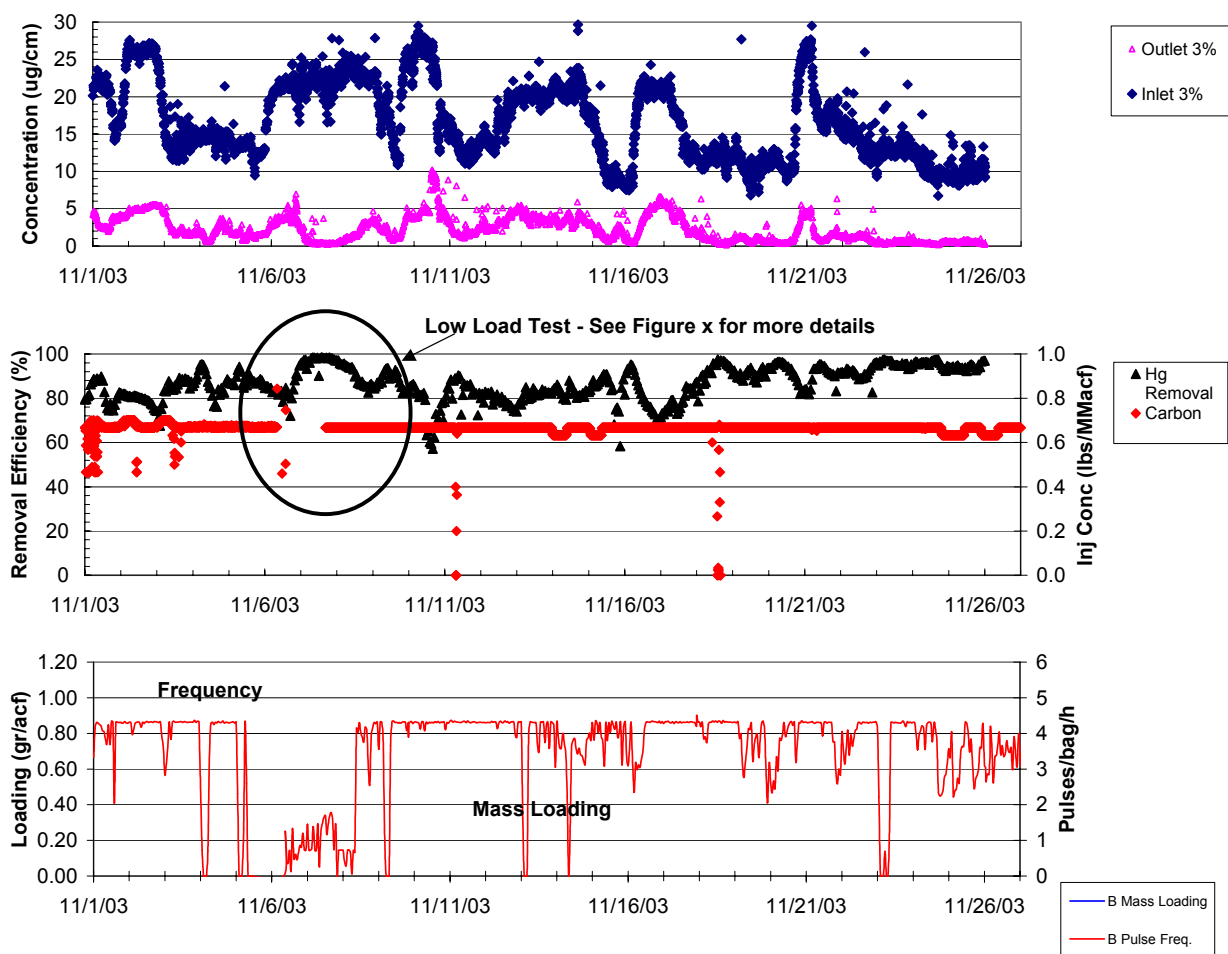


Figure 2. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC™ cleaning frequency and inlet mass loading on Unit 3B COHPAC™ from November 1 through November 26.

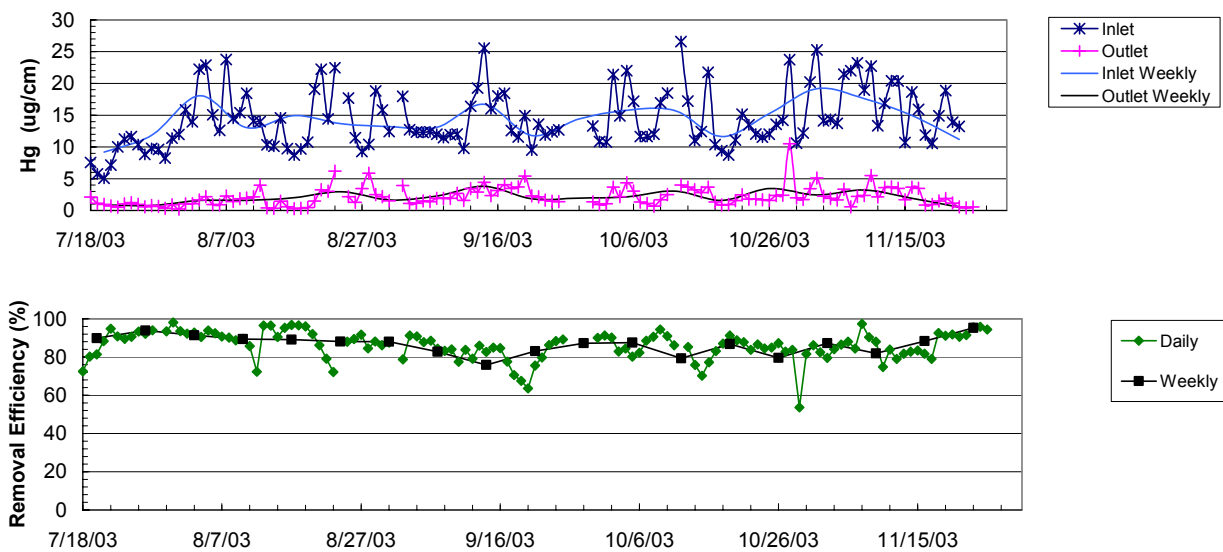


Figure 3. Daily and weekly averages of inlet and outlet mercury concentrations and mercury removal from July 19 through November 23.

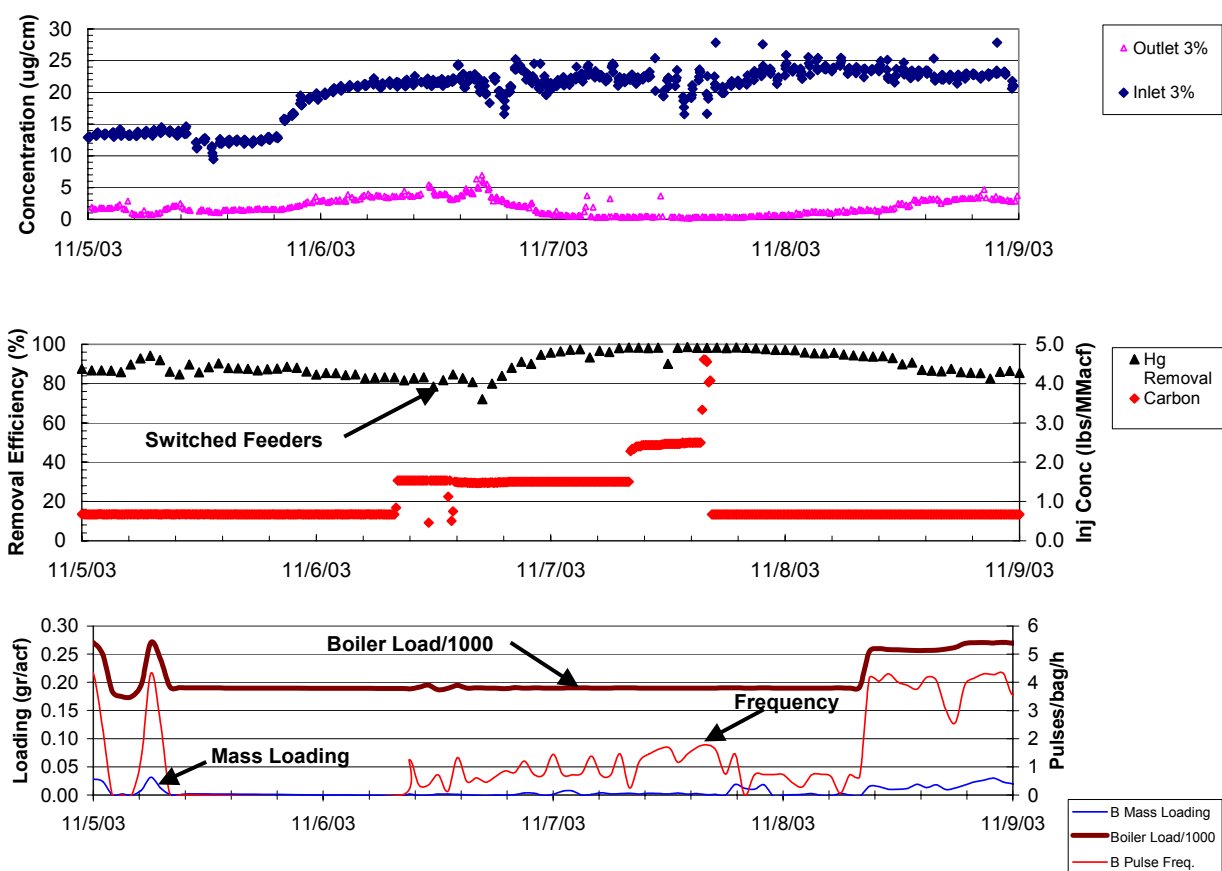


Figure 4. Inlet and outlet mercury concentrations, removal efficiency, activated carbon injection concentration, COHPAC™ cleaning frequency, and inlet mass loading on Unit 3B COHPAC™, and Unit 3 boiler load during low load tests, November 5 through November 9.

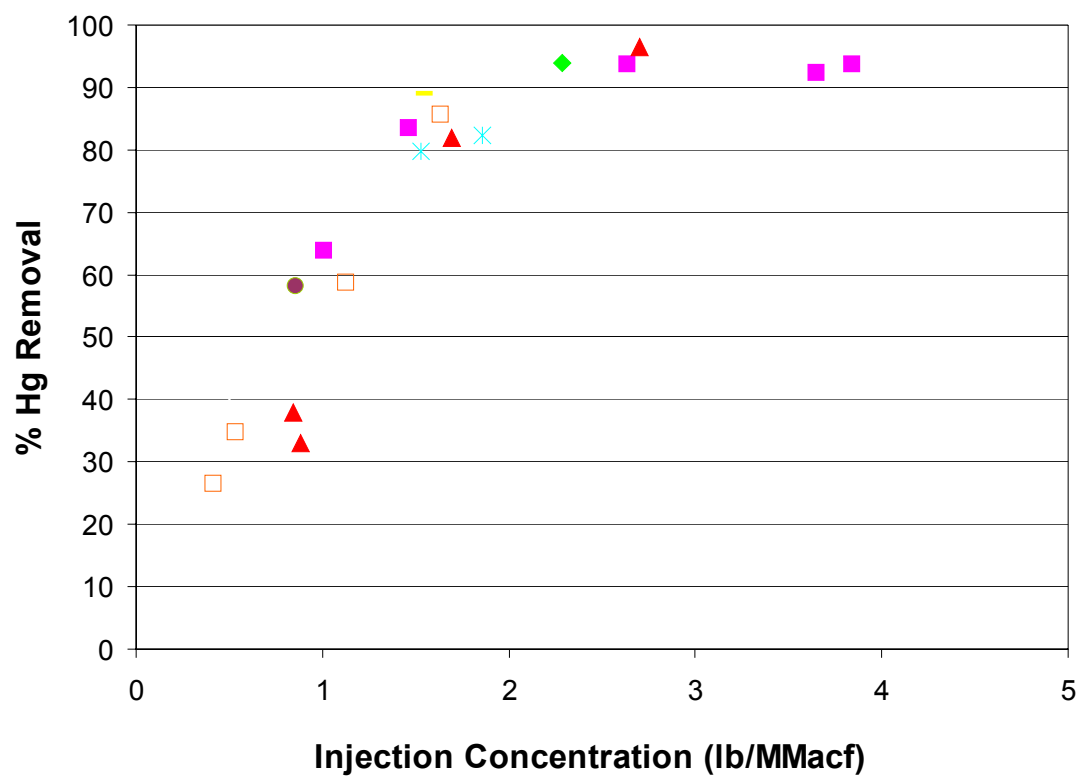


Figure 5. Results from Phase I parametric testing with activated carbon, March – April 2001.

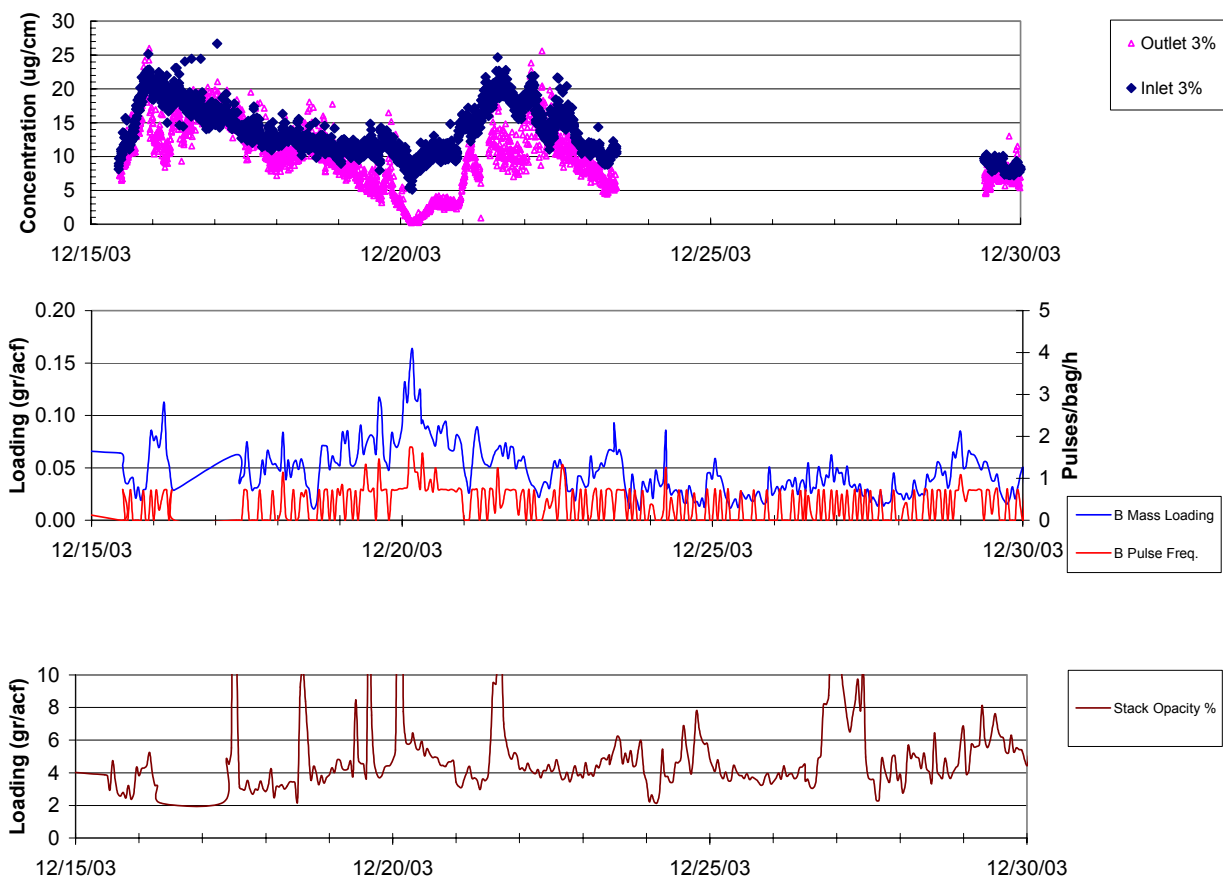


Figure 6. Inlet and outlet mercury concentrations, COHPAC™ cleaning frequency and inlet mass loading on Unit 3B COHPAC™, and Units 3 and 4 stack opacity from December 15 through December 30.

Appendix A

Gaston Unit 3 BH visit

Date: 7 Oct 03

Inleakage at cell outlet guillotines:

The seals on the outlet guillotine dampers have worn away such that they now allow a significant amount of ambient air inleakage. We temporarily plugged the gap, which reduced the inleakage to a small amount, to see if reported BH DP would be reduced. BH temperature drop was reduced by 20-30 degrees, as indicated on the BH outlet temperature readings. There was no noticeable effect on the BH DP.

Pulse cleaning hardware:

- * The rotating arms were all operating normally,
- * All pulse valves appeared to be operating properly,
- * The pulse pressure in the pulse tanks was an average of 10 psi (9.75 to 11 psi).
- * All pulse tanks were emptying and refilling as expected.
 - * The 2 inch, chain wheel operated, pulse tank inlet valves are all fully open. This is not actually necessary (somewhere between 25% and 50% open would be sufficient), and this will actually increase the volume of air in each pulse. As long as the cleaning air blowers can provide sufficient air, this is not at all a problem.

Cleaning frequency:

The pulse frequency was doubled for a trial period from Noon to 240 pm, from pulsing every pulse tank once each 20 seconds to once each 10 seconds. The pulse pressure remained the same at an average of 10 psi.

This did reduce the BH DP on the A side BH. This BH then only pulsed half of the time. But with the doubled pulse frequency, the total number of pulses was the same. The double pulse frequency has less effect on the B side BH. This BH had a higher inlet loading, and only occasionally reached a DP low enough to stop pulsing continually.

Since we were not completely sure whether this mode of operation was considered any 'better' for the mercury removal testing, and the testing crew preferred that the BH operation be the same as it had been for the past week, we returned the pulse frequency to the same value as it was initially.

It was unfortunate that Byron Corina was not on site at the time of my visit.

High BH DP:

I believe everyone is aware that the ESPs upstream from the BH, are not operating as efficiently as they used to. This is reportedly due to some discharge electrodes being shorted out inside the ESP casing, some failed TRs and one TR providing power to more than one field of DEs.

Summary / Recommendations:

The BH is operating as well as can be expected. If the aim is to increase the amount of carbon injected into the BH inlet duct, you will have to pulse faster and/or reduce the particulate loading from the ESP outlet, or simply operate the BH at a higher DP. (At the plant, I was not able to determine limiting factors of such operation.)

Regards,

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Appendix B

In order to better understand the differences between the 2001 PAC injection campaign and the 2003 PAC injection campaign at Gaston, additional analyses of ash from 2001 and 2003 were undertaken. These analyses include:

- Particle size distribution by Malvern analysis (light scattering)
- N₂ BET surface area
- Petrography (analysis of coal macerals)
- Ultimate analysis
- Microscopy

Table 1 shows which samples were analyzed. Petrographic and ultimate analyses were carried out by Jim Hower at the University of Kentucky, Center for Applied Energy Research. Microscopy was carried out by Microbeam Technologies.

Table 1. Analyses performed on Gaston ash samples.

Sample ID	MTI ID	Date/Time	Sample Location	Hg content	LOI	Malvern	BET SA, m ² /g	Ultimate Analysis	Petrography
GAS00137	01-212	4/23/2001	HESP	X	X	X			
GAS00140	01-113	4/24/2001	HESP	X	X	X			
GAS00141	01-114	4/24/2001	A-side BH	X	X	X			
GAS00146	01-117	4/25/2001	HESP	X	X	X	X		
GAS00147	01-118	4/25/2001	A-side BH	X	X	X	X		
GAS00152	01-121	4/26/2001	HESP	X	X	X	X	X	X
GAS00153	01-122	4/26/2001	A-side BH	X	X	X	X	X	X
GAS00203	03-190	4/2/2003	B-side BH	X	X	X	X	X	X
GAS00204	03-191	4/2/2003	HESP	X	X	X	X	X	X
GAS00205	03-192	4/2/2003	A-side BH	X	X	X	X	X	X
GAS00265	03-199	5/14/2003	A-side BH	X	X	X	X		
GAS00266	03-200	5/14/2003	B-side BH	X	X	X	X		
GAS00267	03-201	5/14/2003	HESP	X	X	X	X		

Particle size distribution measurements are shown in Figures 1 and 2 as cumulative volume distributions. The A-side ash particle size distributions are distinct from the hot-side ESP samples. The hot-side ESP samples have larger particles than the A-side samples and there is no significant difference between the hot-side samples from 2001 and 2003. The A-side samples for 2003 are significantly different from the 2001 samples in that the former contain more large particles. The size distribution of the 2001 A-side ash is finer than the 2003 ash. Generally, the 2001 ash has few particles greater than 25-50 microns, even though these particles are found in the HESP ash. The collection efficiency of the hot-side ESP is such that the larger particles did not reach the baghouse in 2001. However, one sample of 2003 ash from 5/14/03 contained very large ash particles, comparable to the largest particles in the

HESP ash. The variability in the 2003 A-side ESP ash suggests that the hot-side ESP was not operating in a consistently efficient manner, and that more large particles were getting through the hot-side ESP in 2003 as compared to 2001.

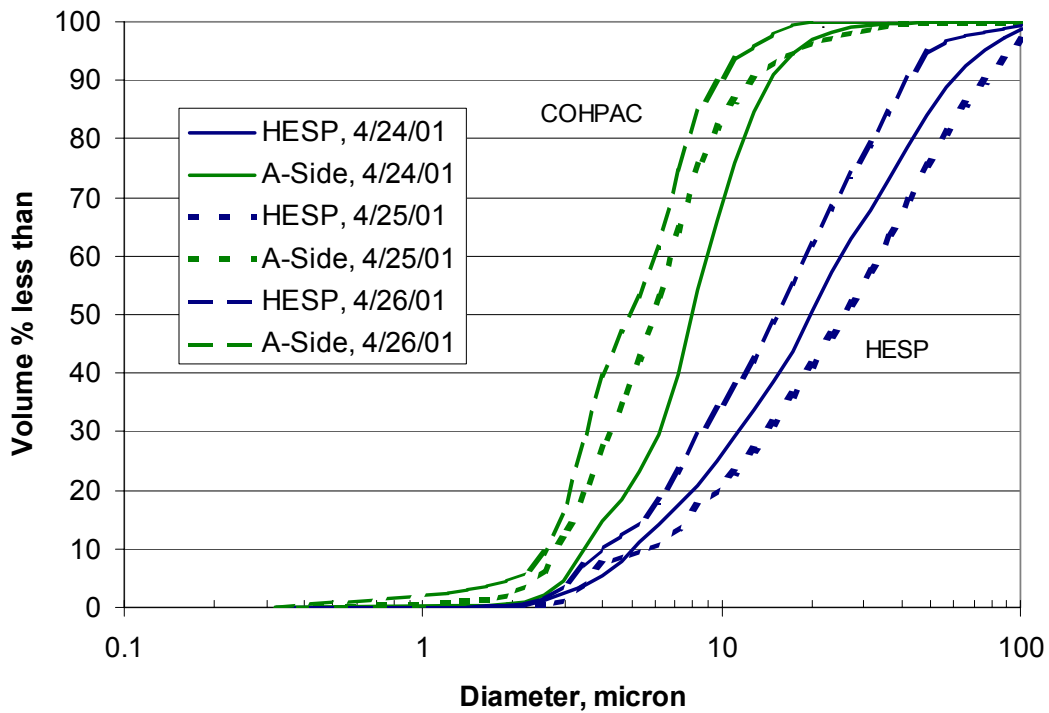


Figure 1. Cumulative particle size distribution of 2001 ash samples.

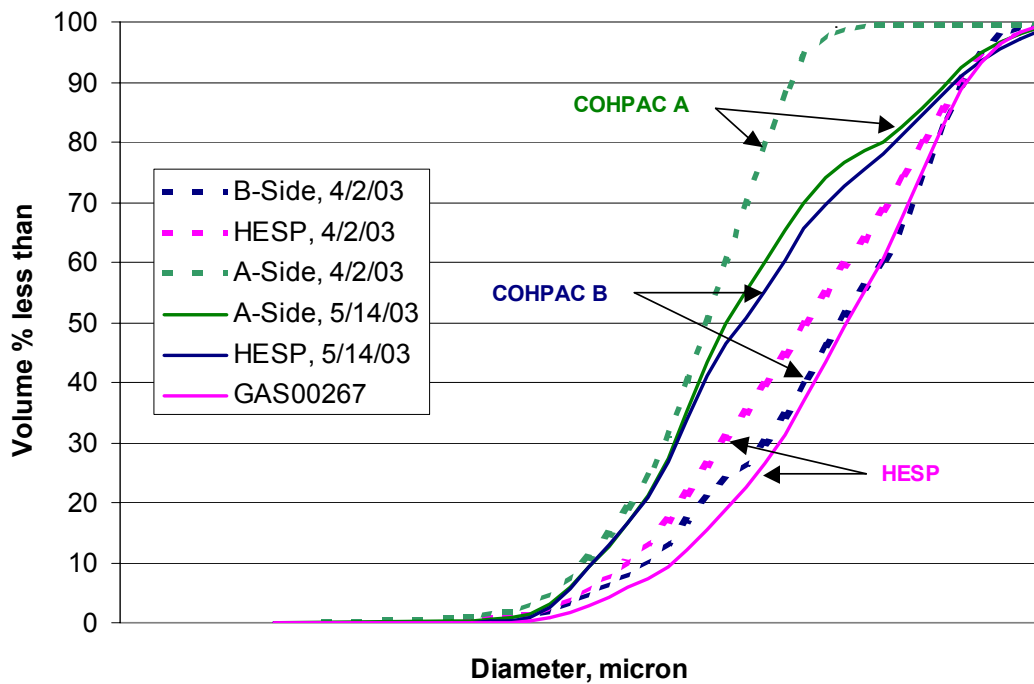


Figure 2. Cumulative particle size distribution of 2003 ash samples.

Tables 2 and 3 give the results of carbon maceral analysis and ultimate analysis of ash samples carried out at the University of Kentucky. Ultimate analysis was carried out because the LOI values previously measured for the A-side ash samples seemed to be high, considering the color of the ash and its maceral content.

Table 2. Petrographic analysis of ash samples, volume % of phase.

Sample ID	MTI-ID	Sample	glass	mullite	spinel	quartz	isotropic coke	anisotropic coke	inertinite	oxidized material
GAS00152	01-121	HESP	78.0	0.0	2.0	0.0	10.0	7.8	2.6	
GAS00153	01-122	A-side BH	93.2	0.0	0.4	0.2	1.8	3.8	0.6	
GAS00203	03-190	B-side BH	60.8	0.0	2.4	0.4	16.8	16.8	2.8	
GAS00204	03-191	HESP	73.0	0.6	3.2	0.0	11.4	8.8	2.8	
GAS00205	03-192	A-side BH	90.2	0.0	1.4	0.0	1.4	5.6	1.2	0.2

Table 3. Ultimate analysis of ash samples, wt %.

Sample ID	MTI-ID	Sample	%Ash	%Moisture	%C	%H	%N	%S	%O
GAS00152	01-121	HESP	87.3	0.19	12.26	0.11	0.14	0.2	<0.01
GAS00153	01-122	A-side BH	83.81	1.24	7.8	0.37	0.14	2.1	5.78
GAS00203	03-190	B-side BH	81.72	0.3	17.	0.12	0.21	0.54	0.41
GAS00204	03-191	HESP	85.73	0.14	14.11	0.04	0.16	0.36	<0.01
GAS00205	03-192	A-side BH	83.56	2.57	5.13	0.63	0.1	2.33	8.25

The results of the petrographic analyses are shown in Figure 3.

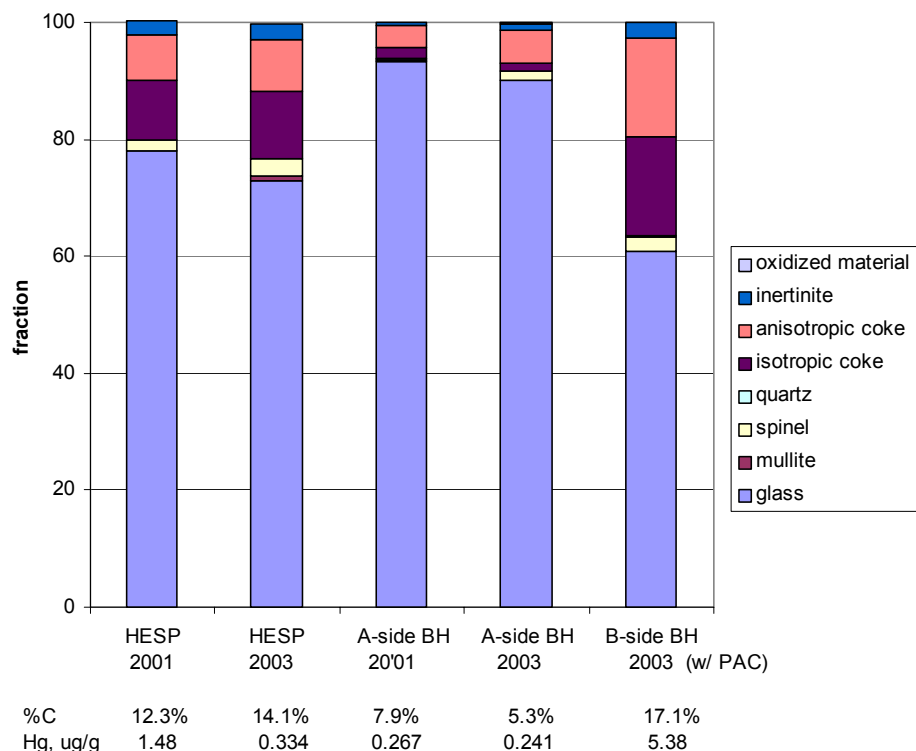


Figure 3. Petrographic analysis, volume % of phase.

The A-side ash has LOI values comparable to the hot-side ESP ash. However, the carbon content of the A-side ash is lower than the carbon content of the hot-side ESP ash. The measured amounts of LOI agree well with the measured amounts of carbon for the hot-side ESP ash and the B-side ash sample (containing activated carbon). The measured amount of carbon in the A-side ash is considerably lower than the LOI. From the ultimate analysis of the ash, we can see that the A-side ash has a significant amount of moisture, sulfur and oxygen, unlike the hot-side ash samples and the B-side sample. Based on two sets of samples, therefore, it appears that the LOI content of the A-side ash is misleading, in terms of the amount of carbon in the ash.

SEM micrographs of polished cross-sections of ash illustrate qualitatively the petrographic analysis. Figure 4 shows a hot-side ESP ash sample from 2001. Spherical ash particles can be seen as well as darker and more irregular unburned carbon particles, which are on the order of 100 microns. The 2003 hot-side ESP ash (Figure 5) contains the same types of particles.



Figure 4. Polished cross-section of hot-side ESP ash (GAS00152), 4/26/01.

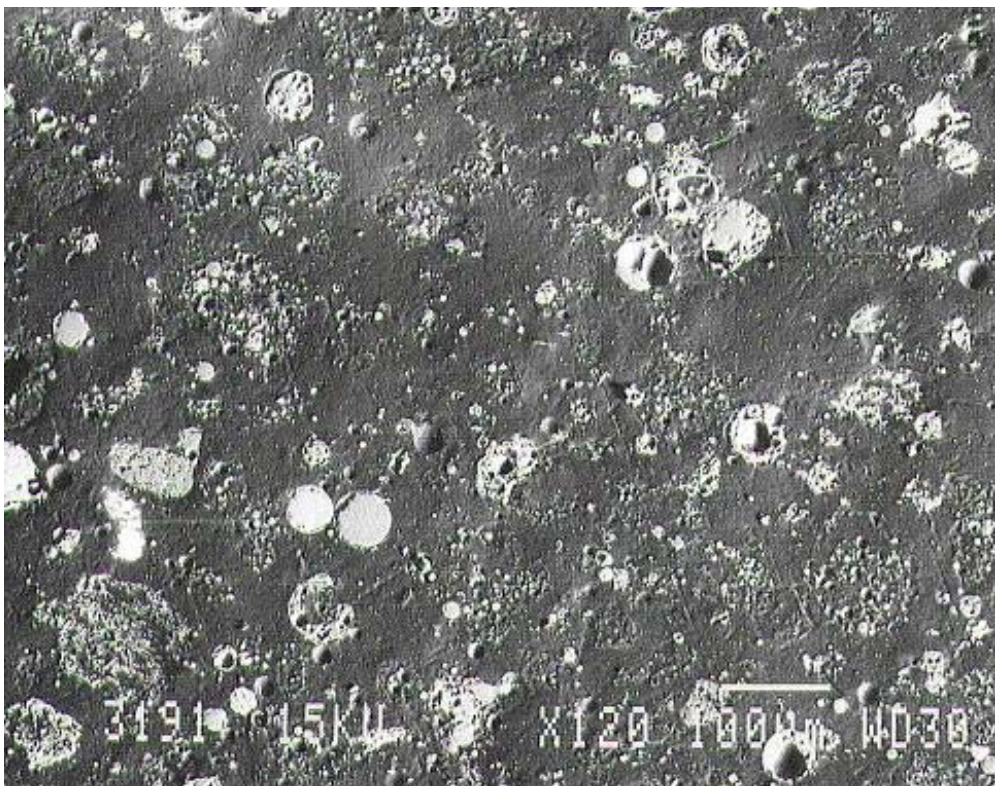


Figure 5. Polished cross-section of hot-side ESP ash (GAS00204), 4/2/03.

The hot-side ESP ash in 2003 does not differ greatly from the hot-side ESP ash from 2001 in terms of the carbon maceral content or particle size distribution. The surface area of the 2003 hot-side ESP ash is higher than in 2001.

As the particle size distributions indicate, the A-side ash is considerably finer than the hot-side ESP ash. This is illustrated in the photograph of the A-side ash in Figure 6. There are few of the large, bright spheres and only one large, unburned carbon particle (lower right quadrant).



Figure 6. Polished cross-section of A-side ash (GAS00153), 4/26/01.

Particle size distribution, surface area, carbon content and carbon maceral type are all distinct between the hot-side ESP samples and the baghouse ash samples, as summarized in Table 4. The A-side ash has a lower surface area than the hot-side ESP ash. Addition of activated carbon to the baghouse increases the surface area, as one would expect. The surface area of the A-side ash may be higher in 2001 than in 2003, though with only two samples analyzed for each year it is hard to reach a definitive conclusion. The hot-side ESP ash samples have a higher surface area in 2003 than in 2001, though the sample size is small.

The ratios of the major maceral types are distinct for the different ash samples. Table 4 gives the ratio of the anisotropic carbon to the total forms of carbon. The hot-side ash has more isotropic carbon, while the A-side ash has proportionately more anisotropic carbon. Hower

et al.¹ have speculated that anisotropic carbon in fly ash absorbs more mercury from flue gas because this type of carbon has the greatest surface area of the forms of carbon.

Table 4. Summary of ash properties.

Sample ID	MTI ID	Date/Time	Sample Location	Hg, ug/g (AR)	LOI, wt%	%C, dry	BET SA, m ² /g	Fraction Anisotropic Carbon
GAS00137	01-212	4/23/2001	HESP	3.08	16.2%			
GAS00140	01-113	4/24/2001	HESP	0.0024	10.4%			
GAS00141	01-114	4/24/2001	A-side BH	1.85	12.8%			
GAS00146	01-117	4/25/2001	HESP	1.33	13.1%		5.3	
GAS00147	01-118	4/25/2001	A-side BH	0.187	14.8%		4.15	
GAS00152	01-121	4/26/2001	HESP	1.48	11.9%	12.3%	7.14	0.38
GAS00153	01-122	4/26/2001	A-side BH	0.267	14.7%	7.9%	2.24	0.61
GAS00204	03-191	4/2/2003	HESP	0.334	13.6%	14.1%	12.45	0.38
GAS00205	03-192	4/2/2003	A-side BH	0.241	10.8%	5.3%	1.74	0.68
GAS00203	03-190	4/2/2003	B-side BH	5.38	17.8%	17.1%	10.74	0.46
GAS00267	03-201	5/14/2003	HESP	0.53	13.7%		8.31	
GAS00265	03-199	5/14/2003	A-side BH	0.894	16.5%		2.93	
GAS00266	03-200	5/14/2003	B-side BH	7.61	16.9%		8.72	

¹ Hower, J.C, M.M. Maroto-Valer, D.N. Taulbee, T. Sakulpitakphon “Mercury Capture by Distinct Fly Ash Carbon Forms” *Energy Fuels* **1999**, 14 (1), 224-226.

Conclusions

Particle size distribution, surface area, carbon content and carbon maceral type are all distinct between the hot-side ESP samples and the baghouse ash samples. The A-side ash has a lower surface area than the hot-side ESP ash, which may be due to differences in the distribution of carbon macerals in the ash. Addition of activated carbon to the baghouse increases the surface area, as one would expect.

The A-side ash has LOI values comparable to the hot-side ESP ash. However, the carbon content of the A-side ash is lower than the carbon content of the hot-side ESP ash. The measured amounts of LOI agree well with the measured amounts of carbon for the hot-side ESP ash and the B-side ash sample (containing activated carbon). The measured amount of carbon in the A-side ash is considerably lower than the LOI. Based on the ultimate analysis of the ash, the A-side ash has a significant amount of moisture, sulfur and oxygen, unlike the hot-side ash samples and the B-side sample. Based on two sets of samples, therefore, it appears that the LOI content of the A-side ash is misleading, in terms of the amount of carbon in the ash.

The hot-side ESP ash in 2003 does not differ greatly from the hot-side ESP ash from 2001 in terms of the carbon maceral content or particle size distribution. The surface area of the 2003 hot-side ESP ash is higher than in 2001. Thus, it is hard to determine if the boiler produced the same kind of ash in 2003 as in 2001. Since the number of samples measured was small (and different coals are burned in the boiler on a continually changing basis), it may be difficult to conclude with certainty that the combustion conditions are the same.

The A-side samples for 2003 are significantly different from the 2001 samples in that the former contain more large particles. The variability in the 2003 A-side ESP ash suggests that the hot-side ESP is not operating in a consistently efficient manner, and that more large particles are getting through the hot-side ESP in 2003 as compared to 2001.